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Research paper

Fuzzy LPCM controlled buck integrated PFC converter for Class-C&D appliances

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Abstract

This propounded a novel method of design and implementation of a fuzzy linear peak current mode (LPCM) controlled Buck Integrated Power Factor Correction (PFC) Converter. It derives its advantages through low buck capacitor voltage and single control switch, which leads to reduced complex control and price. Sub-harmonic oscillations generates in peak current controller can be nullified by using ramp signal, there by improves the overall performance of the converter. The fuzzy controller (FLC) robust and effective than conventional linear controllers like P, PI, PID, hence in this work a (90 – 265V), 50Hz AC, 48V DC and 100 kHz frequency converter is implemented in MATLAB/Simulink software and results are verified experimentally. Results show that converter meets international regularity commission regulations.

Keywords: *Fuzzy Controller; Linear Peak Current Control; Buck Integrated Converter; Power Factor.*

1. Introduction

There are numerous types of loads which operate with power factor (PF) ranging from zero to one. However, the PF close to one is always desirable. Based on the performance of loads in terms of PF, % harmonics and other parameters, IEC has proposed IEC-61000-3-2 standards, which classifies loads into four classes (A, B, C & D).This paper focuses on technique to improve PF in-order to meet these standards Particularly Class C&D loads. There are several passive and active techniques proposed in literature to improve the same. However due to better control and performance active techniques are preferable over passive ones [1]. This paper proposes to integrate advantages of both techniques while getting rid of their limitations. Proposed model uses one single switch, which is used by both PFC and PC stage. Performance of this converter is par with two satge topology with reduced number of components. PFC converter in this paper is realized by integrating buck and flyback converters. The load is fed from the source through buck and flyback converters, both are operating in DCM mode to deliver high PF [2], [3], [4]. In recent year, an Artificial Intelligent technique like Fuzzy control is adopted to improve the gains of the controllers to give better performance. Fuzzy control system uses the knowledge, experience and intelligence of a human expert to make decisions about the behavior of the system [5], [6], [7], [8]

In this paper, analysis and design fuzzy LPCM controlled buck integrated flyback converter is accomplished for Class-C&D appliances to reach nearly unity PF and regulated output.

2. Buck integrated flyback PFC converter

In this paper by using features of buck and flyback converter an integrated PFC converter is considered which integrated buck flyback converter, shown in Fig.1 is. Buck Converter consists of Lb, Dc, Da, SW1, Cb, Vp and Flyback Converter consists of Cb, SW1, 1: m, Db, Da, Dd, Co. SW1 shares both converters.

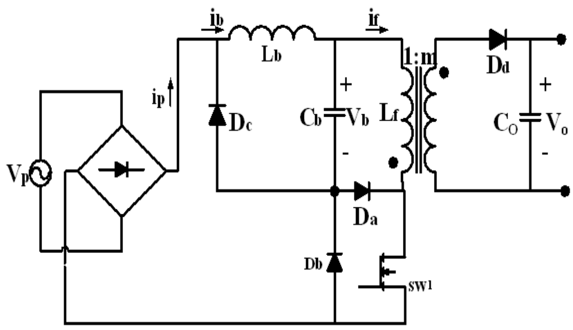

Fig. 1: Integrated PFC Converter.

Operation of this converter can be understood in 4 stages,
During stage 1, SW1 is closed; inductor Lb and Lf gets charged up from source current in the primary, while in secondary diode Dd is reverse biased. Therefore by flyback concept secondary inductor gets charged. Output capacitor (Co) discharges through the load.
During stage 2, SW1 is opened; inductor (Lb) current continuous to flow through Cb and secondary inductance supplies the current to the load.
During stage 3, energy stored in Lb is completely transferred to Cb and load continues to get the energy from Ls.

4th Stage is begins, when Ls energy is exhausted and Co is supplies load. Fig.2 shows Working of converter.

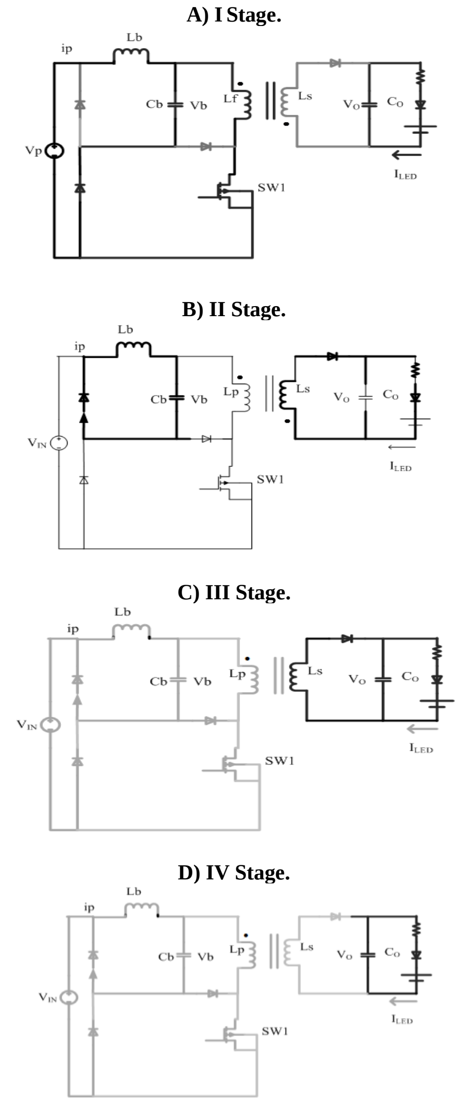

Fig. 2: Operating stages of Integrated PFC Converter.

3. Design of fuzzy LPCM controlled integrated converter

The non-linear and imprecise nature of the problem can be effectively solved by using fuzzy logic which gives better performance and reduces the development cost of the end product. The fuzzy LPCM controlled integrated PFC converter is shown in Fig.3.

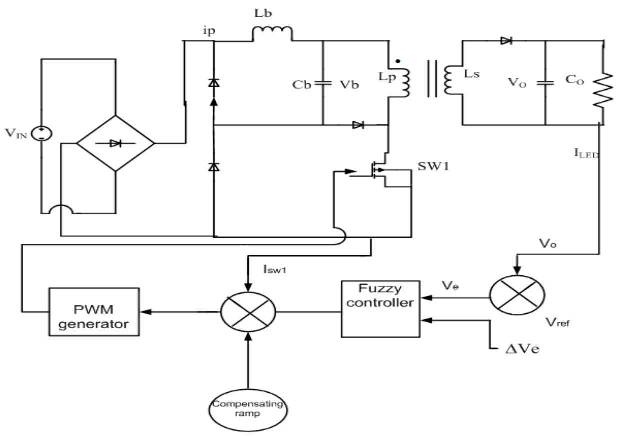

Fig. 3: Block Diagram of Fuzzy Linear Peak Current Controlled Integrated PFC Converter.

3.1. Identification of inputs and outputs

The inputs to the fuzzy controller are error (e) and change of error (ce), i.e, e = Vo – Vref & ce = e (k) – e (k-1), where V0 is the actual output, Vref is the reference output.

3.2. Fuzzifying the inputs and outputs

The inputs are divided triangular shapes of 7 fuzzy sets. Outputs are mapped into fuzzy regions. Fig.4 is membership functions for Inputs & outputs.

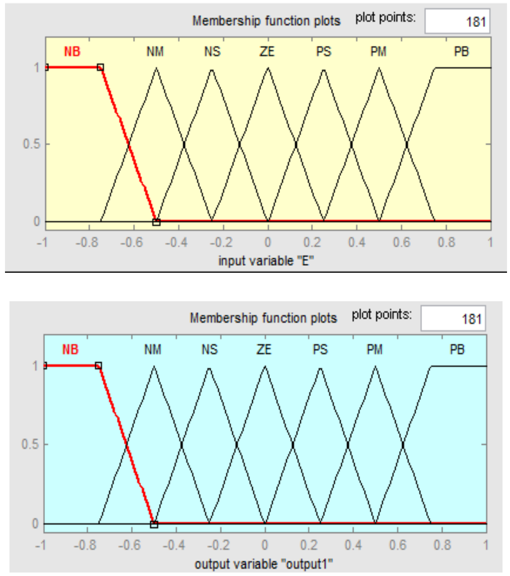

Fig. 4: Membership Function Plots.

3.3. Development of the rule base and inference

The rules base table for the present converter is shown in Table 1.The member ship functions of 7 variable fuzzy sets, those are negative large (N1),negative medium(N2),negative small(N3),zero(Z),positive large (P1),positive medium(P2), positive small(P3). Triangular shapes are used as a membership function for defuzzification process center of gravity method is used.Rule viewer is shown in Fig.5

Tabel 1: FLC Rule Base

	E						
CE	N1	N2	N3	Z	P1	P2	P3
	N1	N1	N1	N1	N3	N2	N3
	N2	N1	N1	N1	N2	N3	Z
	N3	N1	N1	N2	N1	Z	P3
	Z	N1	N2	N3	Z	P3	P2
	P3	N2	N3	Z	P3	P2	P1
	P2	N3	Z	P3	P2	P1	P1
	P1	Z	P3	P2	P1	P1	P1

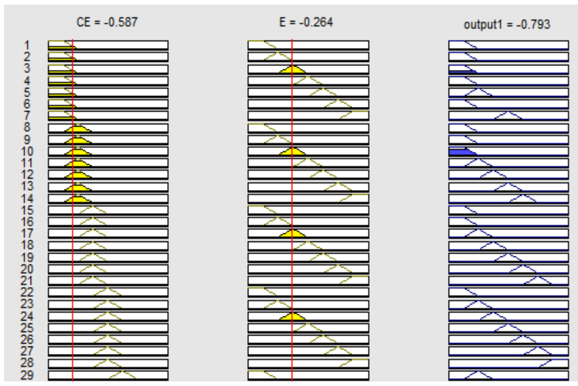

Fig. 5: Rule Viewer.

4. Design example

To meet IEC regulations, considered conduction angle is 1300 to reach highest PF of 0.96 as in ref [4]. Table.2 shows few defined specifications.

Table 2: Design Specifications

Parameter	Value
AC Source voltage (V_p)	90-265 V
Load DC voltage(V_o)	48V
Power (P_o)	200 W
Conduction angle (θ)	130^0
Switching frequency (f_s)	100 KHz

5. Results

Fig. 7 shows the implementation of fuzzy peak current controlled integrated PFC converter using MATLAB/Simulink.

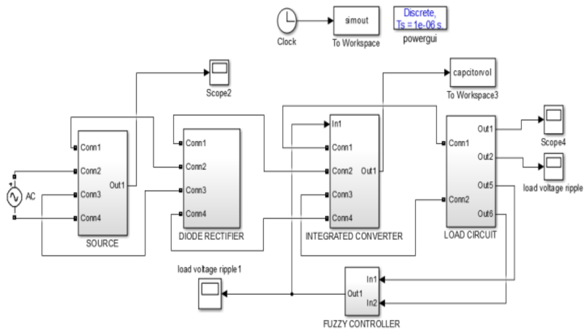

Fig. 7: Matlab/Simulink Model of Fuzzy Peak Current Controlled Integrated PFC Converter.

Fig.8 is the AC source voltage & current wave form for 230V (R.M.S) with frequency of 50Hz source current follows the voltage and maintains nearly unity power factor at full load condition. The power factor & source current harmonic percentage are 0.98 and 13%.

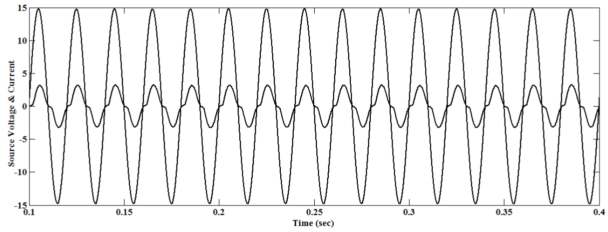

Fig. 8: Line Current (A) & Voltage (V) At 230V, 50Hz Supply.

Fig.9 is the load voltage of 48V DC which is the regulated voltage.Fig.10 is the load current of 4.2A DC waveform which is the current taken by the load to meet the 200 W load.

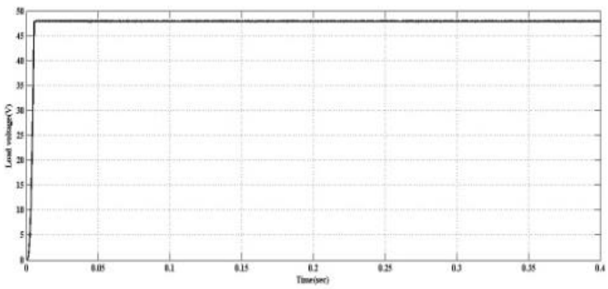

Fig. 9: Voltage at Load (V).

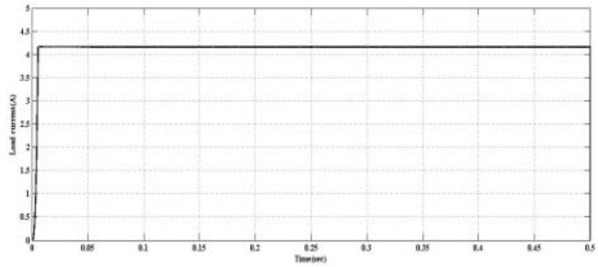

Fig. 10: Current through Load (A).

Fig.11 is the voltage across bus capacitor (Cb) is approximately 140V, which is low as compared to other converters.

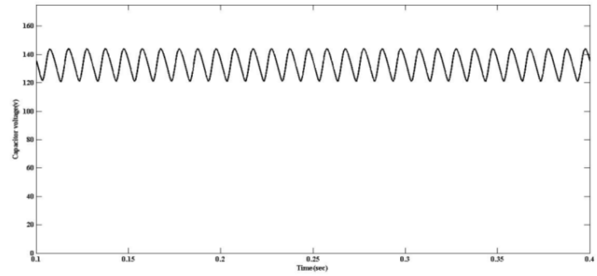

Fig. 11: Capacitor Voltage (V).

Performance of the converter is recorded by varying load from 200W to 100W at 0.25sec depicted in the Fig.12. The observed PF and % THD are 0.97 and 18% respectively.

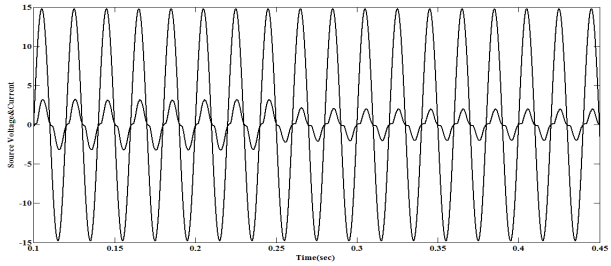

Fig. 12: AC Source Voltage & Current Step-Change at 0.25sec.

The results are also recorded by varying the load. It is observed that output voltage is constant despite of change in the load. Therefore output voltage is well regulated. The same fact is depicted in Fig.13 & Fig.14.

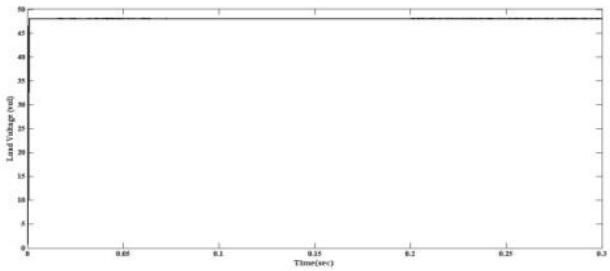

Fig. 13: Load DC Voltage (V) Change of Load at 0.25sec.

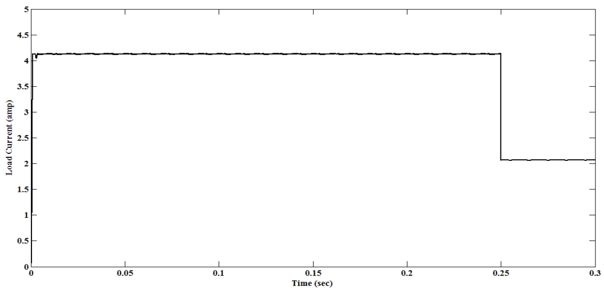

Fig. 14: Load DC Current with Change of Load.

6. Experimental results

Hardware model was realized in the laboratory to investigate the performance of the proposed fuzzy LPCM controlled converter for source voltage of 230V, 50Hz. The AC source voltage & current waveforms, Load DC voltage & load DC current waveforms, and harmonics content of the source current are observed. Fig.14 shows the experimental model of proposed converter with controller. Fig.15 shows the AC source voltage & current waveform with full load at 230V which is similar to the obtained simulation result. Fig.16 shows the AC source voltage & current waveform with full load at 110V. In Fig.17 load DC current is $i_5$waveform and v_5 is load DC voltage waveform. Fig.20 is the bus capacitor voltage waveform.Experimental result for universal input voltage range (90 V -230 V) is shown in Table .3, from that power factor and THD are reaches the international standard.

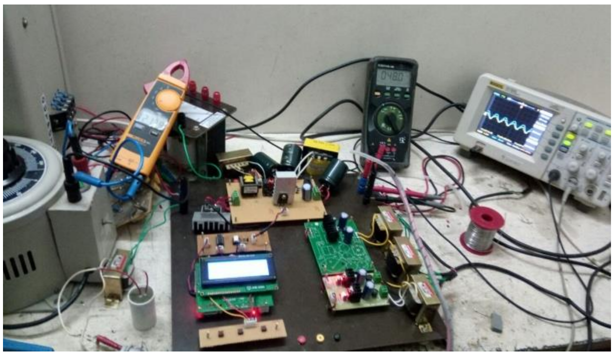

Fig. 15: Proto Type of IBFC.

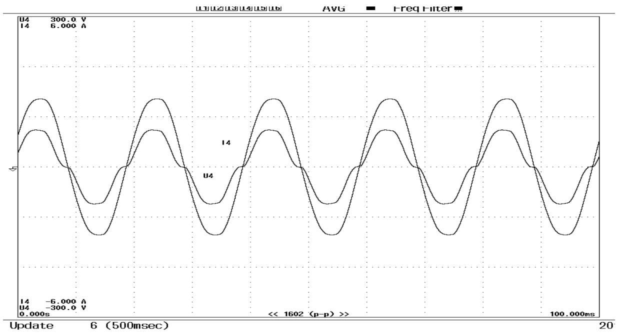

Fig. 16: Experimental Results for Source Voltage (V) and Current (A) for 230V (RMS) at Full Load.

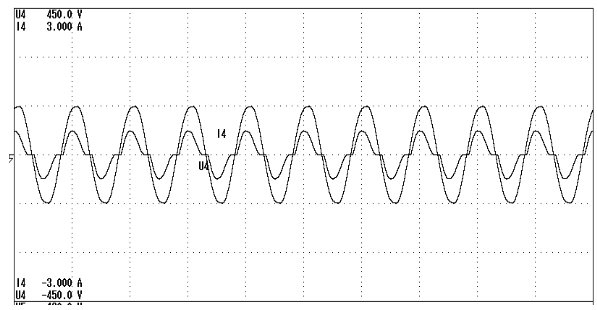

Fig. 17: Experimental Results for Source Voltage (V) and Current (A) for for 110V (RMS) at Full Load.

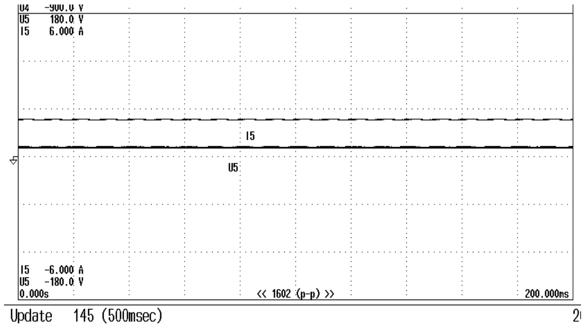

Fig. 18: Load Voltage (V) and Current (A).

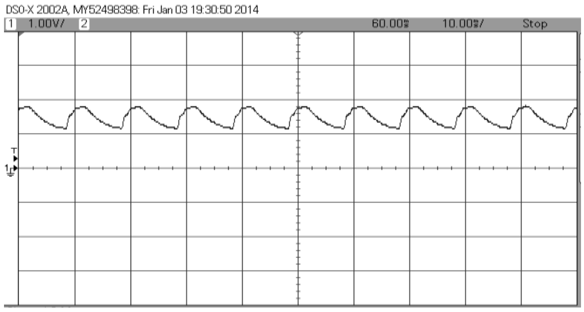

Fig. 19: Bulk Capacitor Voltage.

Table 3: Comparison between Software and Hardware Performance

	Software Results	Hard Results
AC source Voltage	230	231
DC Voltage	48	48
Current harmonics (%)	13	13.234
PF	0.98	0.976

7. Conclusion

Design and implementation of fuzzy LPCM controlled buck integrated flyback PFC converter has been presented in this paper. Simulation results are verified with experimental setup. From the experimental results, it has been observed that the PF of the converter is 0.976, total harmonic distortion is 13.234% at full load which is reachong the international standards IEC-61000-3-2 to class-C & D devices and regulated load voltage is 48V has been achieved. Bulk capacitor voltage is 150 V at light load condition which is low as compared to other integrated topologies.

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